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ABSTRACT

Learner preferences for varying screen density levels were examined using multiple screen designs (high external validity) and single screen designs (high internal validity). Subjects were 23 graduate and 23 undergraduate student volunteers. When viewing multiple screens for each design in Study I, they indicated the highest preference for medium density screens while tending to select higher-density over lower-density screens in individual comparisons. When viewing only the first screen of each density level in Study II, subjects again expressed preferences for higher-density over lower-density designs. Suggestions are provided concerning the use of realistic and nonrealistic content for the stimulus materials as well as implications of using externally and internally valid screen designs for future research on computer-based screen design. (36 references) (Author/BBM)

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Title:

Learner Preferences for Varying Screen Densities Using Realistic Stimulus Materials with Single and Multiple Screen Designs

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Abstract

Learner preferences for varying screen density levels were examined using multiple screen designs (high external validity) and single screen designs (high internal validity). When viewing multiple screens for each design in Study I, subjects indicated the highest preference for medium density screens while tending to select higher-density over lower-density screens in individual comparisons. When viewing only the first screen of each density level in Study II, subjects again expressed preferences for higher-density over lower-density designs. Suggestions are provided concerning the use of realistic and nonrealistic content for the stimulus materials as well as implications of using externally and internally valid screen designs for future research on computer-based instruction screen design.

The continuing expansion of the microcomputer into schools, businesses, hospitals, and homes has created a market for instructional software ranging from beginning mathematics programs to sophisticated simulations of hospital emergency room events. A review of these instructional packages indicates the integration of graphics, sound, animation, and both effective and poor applications of instructional design (Bork 1987; Burke, 1981; Keller, 1987). Unfortunately, software designers have a tendency to design computer screens based on principles derived from print based research (e.g., Hartley, 1985), yet a comparison of the attributes of the two media reveals several important differences. Computer displays (a) are limited to one page at a time, (b) have restricted backward paging and review, (c) are limited to layouts of 40 or 80 columns by 24 rows, (d) provide limited cues as to lesson length, (e) are typically limited to one typeface and one or two typesizes, and (f) offer relatively poor resolution. In contrast to the printed page, the computer has the capability to generate dynamic "pages" (e.g., windows, screen building, and animation), which can be increased in number with a relatively smaller effect on distribution costs.

Computer Screen Design

The literature on computer screen design tends to follow one of two approaches. The first approach focuses on typographical variables that the designer can manipulate to create an effective screen design. Based on research and subjective views, several authors have recommended that displays feature liberal white space, double spacing, a standard ASCII typeface, and left-justified text (Allessi & Trollip, 1985; Bork, 1984, 1987; Grabinger, 1983; Heines, 1984; Hooper & Hannafin, 1986). Given the recent introduction of bit mapped graphics, information concerning the manipulation of typefaces, type size, leading, and similar typographical variables will also become more accessible.

A second approach to computer screen design is the manipulation of the content. One such method is chunking the material into meaningful thought units which are then presented with blank (white) spaces bordering each (Bassett, 1985; Feibel, 1984; Grabinger 1983). Although Falio and DeBloois (1988) suggest chunking as an effective means of designing displays, research on chunking and similar methods have failed to show clear advantages under either print or CBI (cf. Basset, 1985; Carver, 1970; Fiebel, 1984; Gerrel & Mason, 1983; O'Shea & Sinclair, 1983). It seems important to consider that chunking does not change the instructional

content; rather, it changes the way the content is presented on the screen. In contrast, Morrison, Ross, & O'Dell (1988; Ross, Morrison, & O'Dell, 1988) varied the text density in presentations as represented by the length of the materials, redundancy of explanations, and depth of contextual support for main ideas. They found that the lower density text was read significantly faster than conventional text with no reduction in achievement. Subjects also chose lower-density over higher-density text 65% of the time.

In summary, these two approaches, typographical variables and content manipulation, have provided useful guidelines for screen design; however, they have not addressed the issue of how much information, "screen density," the expository frame should contain. For example, the International Reading Association Computer and Technology Reading Committee (1984) recommends using "clear and legible" displays with "appropriate margins and interline spacing", but provides no operational guidelines or specifications to define these qualities. To provide designers with clearer recommendations for optimum density levels, the screen density construct must be operationalized and precisely defined.

Screen Density as a Design Variable

One method of evaluating screen designs is to calculate the density of the total screen by determining how many of the screen spaces contain a character or are adjacent to a character (Tullis, 1983). It is assumed that instructional displays are relatively uniform in density due to the use of prose, as compared to instrumentation readout displays which often chunk the information into different sections of the screen.

Human factors research suggests that performance error rates increase as the density of a display increases (Burns, 1979, Coffey, 1961; Mackworth, 1976; Ringel and Hammer, 1964). Research, however, on the upper limit of screen density has yielded disparate recommendations ranging from 15% (Danchak, 1976) to 31.2% (Smith, 1980, 1981, 1982) all the way to 60% (NASA, 1980). Two reasons for these inconsistencies are suggested. First, the displays have often involved instrumentation screens and information displays that are too esoteric (i.e., unique to a specific environment) to be generalizeable to instructional screens. Second, several of the studies have used isolated screen displays of unrealistic stimulus materials which have low ecological validity (see Ross & Morrison, 1989).

In a realistic lesson the number of frames increases as the amount of white space increases (i.e., screen density is decreased). Thus, manipulation of screen density in a single frame presentation fails to account for the concomitant effect of the increase or decrease in the number of screens required to read the same information.

Accordingly, in contrast with previous research, the present study was designed to examine learner preferences for different screen densities used to present a fixed amount of material. Depending on the particular density level represented, from one to four frames of information were required to view the content.

Another concern in investigating screen density preferences is the possible influence of the type of material presented on how different screen designs are viewed. For example, Grabinger's (1983) evidence for supporting low density screens was obtained using a typographical notation developed by Twyman (1981) to create a content-free screen representation of a CBI screen. Specifically, screens were designed with x's and o's to resemble actual lessons. However, when reacting to displays of abstract or artificial materials, subjects may prefer wide margins and other lower density attributes due to the greater saliency of aesthetic properties when there is no need to understand the content. In contrast, judgments of realistic materials would appear to demand greater awareness of and reliance on contextual properties (e.g., proximal supporting text) that helps to increase the meaning of the information being read. Thus, it is not clear that preferences for low-density screens similarly apply to realistic lesson materials, especially since the low-density designs present the material in smaller thought units and consequently also necessitate an increased number of lesson frames.

Accordingly, to extend Grabinger's (1983) research, the present study used realistic materials from an actual course in the subjects' academic program. We expected that with fixed content and realistic displays, preferences for lower-density screens would not be as high as previous research in the instructional design literature generally suggests. A third research interest was the preferences of users differing in degree of CBI experience, namely graduate instructional design students versus undergraduate education students.

Method

Subjects and Design

Subjects were 23 graduate and 23 undergraduate education majors (29 females and 17 males) who volunteered to participate in the study. A paired-comparison design (Nunnally, 1967) was employed involving a total of six unique pairings of four density levels presented on an Apple IIe monochrome screen. For each of the six comparisons, subjects were presented with two different screen designs and asked to indicate their preference. The six comparisons and the two density levels within each were presented in a random order. To begin the session, subjects completed a 9-item attitude survey presented on the computer. They were then presented the six comparisons and asked to indicate their preference on each.

Materials

Materials used in this study are described below in the order in which they were used.

Profile Data. A 9-item survey was used to determine subjects' attitudes towards using the microcomputer. Each item was presented on the computer screen. Subjects reacted to each using a five-point scale with 5 representing the most positive reaction. Six of the items concerned the subjects' attitudes towards using the microcomputer for work or school. The remaining three items concerned their attitudes towards learning how to use a microcomputer.

Screen Displays. A single screen selected from a computer-based lesson used in previous studies on text density (Morrison, Ross, & O'Dell, 1988; Ross et al., 1988) was selected as the basic content for this study (see Figure 1). The material was from an instructional unit on statistics (Ross, 1983) currently used in an undergraduate education course at the same university in which the study was conducted. To determine the screen density of the core frame, all characters and spaces contiguous to the characters were counted and then divided by the total number of characters the screen could display (960 for a 40 column x 24 row format). The resultant density level was 53% (see Figure 1). The 53% density screen was then divided into two screens, three screens, and four screens to reduce density level by varying degrees. Screens were divided at logical points rather than according to specific character counts which helped maintain a uniform density level across the screens. The density levels for the multiple-screen displays were determined by averaging the density of each screen. The two-screen display had an average density level of 31% per screen, the three-screen display averaged 26%, and the four-screen display averaged 22% (see Figure 1).

The screen display software included a management component which stored the data collected at each session on disk for later retrieval. A second program was used to provide a printout of each subject's responses, reformat the data for uploading to a mainframe for later analysis, and add the data to an archive file for future reference.

Insert Figure 1 About Here

Procedure

From 2 to 15 subjects attended each session in one of two computer labs. Both labs were equipped with Apple //e microcomputers with 12 or 13 in. monochrome screens, either one or two 5.25 in. disk drives, and 64K to 128K of memory. Proctors began the session with a brief description of the purpose of the study after which they booted the computers. The first screen asked subjects for their name, sex, and status (graduate or undergraduate). Then, subjects completed the 9-item attitude survey presented on the microcomputer. Subsequent screens described the experiment and explained the information contained on each screen.

The six screen comparisons were presented in a random order. The density level randomly selected to be presented first in each each comparison was labeled Design #1 at the top of the screen and the second density level was labeled Design #2. The number of screens in the design and the particular screen presently being viewed was indicated in the lower left hand corner (e.g., "1 of 1", "2 of 3", etc.). A prompt in the lower right corner of the screen indicated that a key press would result in advancement to the next frame. After viewing both designs, subjects had the option of indicating their preference for one of the two designs or for reviewing either or both designs. Once a preference was indicated, presentation of the next pair of designs was initiated. This process was then repeated for each of the remaining five comparisons.

Results and Discussion

Paired Comparison Selections

Table 1 shows the proportion of subjects (total n = 46) who selected each density level when paired with each of the alternative levels. These proportions reflect a curvilinear pattern, with preferences tending to favor the two middle density levels (especially the 31% level) over the lowest (22%) and highest (53%) levels. Specifically, the 31% level was favored by the majority of subjects (from 52 to 74 percent) over each of the other three levels; the 26% level was favored by the majority (54 to 56 percent) over each of the two extreme levels.

Insert Table 1 about here

To provide an overall comparison of the density selection rates, a scaling procedure derived from Thurstone's model of comparative judgment (see Nunnally, 1967; Guilford, 1954) was used to represent their relative distances on an interval scale. The procedure involves first converting the proportion values (as shown in Table 1) into normal curve deviates. For example, a stimulus that is chosen over a comparison stimulus by 84% of respondents would have a normal (z score) deviate of 1.00, representing the area in the distribution that is 1 standard deviation above the mean. The normal deviates derived for each stimulus are then averaged to produce an overall mean. To prevent having negative values on the final scale, the absolute value of the largest negative mean is added to each of the means. Consequently, the "least preferred" stimulus on the final scale will always have a final mean value of 0.0. For the present preference scale, as shown in Figure 2, the scale values ranged from 0.0 (22% density) to .49 (31% density). Although the 26% level was preferred over the 53% level in their direct comparison (see above), both had identical scale scores of .19. Based on these overall scale placements, the 31% level can be considered the most frequently preferred and the 22% level the least frequently preferred.

Insert Figure 2 about here

To verify these trends statistically, tabulations were made of the total number of times each density level was chosen by subjects. Because each level was judged on three out of the six comparisons, its maximum score for a given subject was 3.0. Resultant means were 1.17, 1.46, 1.91, and 1.46 for the four density levels, respectively (ordered from lowest to highest density). The density selection scores were then analyzed in two ways. First, a Friedman ANOVA by ranks, a nonparametric test (Hays, 1981), was used to compare their ordinal rankings within subjects. Although this test is less powerful relative to treating the scores as interval data in a parametric test, it was considered less likely to be biased by the built-in interdependency between individual subjects' four selection scores (i.e., if a subject's score for one density level was relatively high, his/her score for one or more other density levels would have to be relatively low to compensate). Results from the Friedman test were significant, $X^2(3) = 8.32$, $p < .04$, indicating that the frequencies with which the density

levels were selected were different. This outcome was then substantiated by performing a repeated measures multivariate analysis of variance (MANOVA) on the original selection total scores, F (3,43) = 3.34, $p < .03$. Follow-up comparisons of means were made using the Tukey HSD procedure. Only the difference between the 31% and 22% levels was significant ($p < .05$).

The above results provide information on how the individual density levels were judged relative to one another. A somewhat different question concerns whether or not overall preferences tended to favor, as the literature suggests, lower-density over higher-density designs. However, tabulations across subjects on the six paired-comparison trials indicated the opposite pattern: 156 (57 percent) selections favored the higher density design whereas only 120 (43%) favored the lower density design, $X^2(1) = 4.44$, $p < .05$.

Individual Differences Outcomes

Further analyses examined density preferences and attitudes as a function of subject gender and academic group (graduate versus undergraduate). Dependent variables were the four density level total scores, the total number of lower density designs selected across trials, and scores on each of the nine attitude items. Using t tests for independent samples, none of the group effects for either individual difference variable was significant. Finally, correlations between the number of lower-density designs selected and attitude scores were consistently low and nonsignificant.

Summary

In contrast to recommendations in the literature (Allessi & Trollip, 1985; Bork, 1984, 1987; Grabinger, 1983; Heines, 1984; Hooper & Hannafin, 1986) for designing lower density screens, these results showed that subjects tended to prefer higher-density screens. The relatively stronger preferences for the 31% (intermediate) density level may suggest that subjects were attempting to balance aesthetic properties (i.e., perceived readability and visual appeal) with either or both (a) the degree of contextual support and (b) the number of screens in the lesson. If the latter were the key factor, then preferences for the lower density (more spacious) designs would seem likely to increase if corresponding increases in the number of screens were presented by presenting only the first screen of each screen density level as in Grabinger's (1983) study. Study II was conducted to test this interpretation.

Study II

The primary interest in Study II was to determine the replicability of the Study I results when only the first screen of each density level was presented. It was predicted that in this case, stronger preference for the lower density screens would be indicated than in Study I, since reductions in density level would not require having to review a greater number of frames.

Method

Subjects and Design

Subjects were 27 graduate and 12 undergraduate education majors (34 females and 5 males) who volunteered to participate in the study and had not participated in Study I. The same paired-comparison design as in Study I was employed.

Materials and Procedures

The stimulus materials were the same as used in Study I with one change. Only the first screen for each density comparison was presented. The instructions were modified to indicate that subjects would view only the first screen of information in the six designs, but in a real lesson they would need to view several screens to obtain all of the relevant information.

As in Study I, the first screen asked subjects for their name, sex, and status (graduate or undergraduate). The 9-item attitude survey was then presented, followed by instructions for the paired-comparison task. The six screen comparisons were presented in a random order, with the density levels in each randomly designated as Design #1 or Design #2 at the top of the screen. Again, subjects had the option of viewing either or both designs as many times as desired before indicating their preference.

Results and Discussion

The proportion of subjects (total n = 39) who selected each density level in the separate comparisons is shown in Table II. Here, in comparison to the curvilinear trend of Study 1, the pattern is directly linear, with the higher-density design consistently preferred over the lower-density design. Application of the linear scaling procedure, as diagrammed in Figure 3, reflects this pattern, showing the scaled scores to increase, from 0.0 to .49, as density level increases. As in Study 1, the total number of times subjects selected each density level were tabulated. Overall means were 1.13, 1.49, 1.62, and 1.77 (out of a possible 3.0) for the four levels respectively. However, neither the Friedman analysis of ordinal rankings nor the repeated measures ANOVA on selection total scores indicated a significant difference between levels, although the latter

approached significance ($p < .08$). Across all comparisons, however, subjects chose the higher-density design 145 (62 percent) times and the lower-density design only 89 (38 percent), X^2 (1) = 12.93, $p < .001$. Thus, compared to Study I, while no particular density level emerged as significantly more or less desirable than others, there was an even stronger tendency to select higher-density design of each pair.

Insert Figure 3 About Here

Individual difference comparisons were made for academic status, but not for gender due to the very small number of males (5 out of 39) in the sample. Differences were significant on the selection totals for two density levels. Undergraduates selected the 31% level an average of 1.08 times (i.e., on 36% of its comparisons) whereas graduate students selected it an average of 1.85 times (a 60% rate), $t(38) = 2.24$, $p < .05$. For the 53% level, the opposite pattern occurred, with the undergraduate students selecting it more frequently ($M = 2.33$, rate = 78%) than the graduate students ($M = 1.51$, rate = 50%), $t(38) = 2.00$, $p < .05$. No differences between graduate and undergraduate students were found on any of the attitude items or on the total number of lower-density designs selected across trials.

Discussion

In contrast to previous studies and recommendations in the instructional design literature (Allessi & Trollip, 1985; Bork, 1984, 1987; Grabinger, 1983; Heines, 1984; Hooper & Hannafin, 1986), subjects in the two studies indicated a strong preference for learning from high density screens as opposed to low-density screens. These results were generally consistent for males and females, and for inexperienced and experienced users. The suggestion is that the use of realistic stimulus materials may produce different results than obtained with nonrealistic stimulus materials (e.g., Grabinger, 1983) or with informational (e.g., machine status) displays (e.g., Danchak, 1976; Smith, 1980, 1981, 1982).

A question still remains as to why subjects indicated a preference for higher density screens over lower density screens in the individual comparisons. If only the results from Study I are considered, one might conclude that higher density screens were selected to avoid the additional effort (keypresses) and presentational discontinuities involved in viewing the additional screens of the lower density version. In Study II, however, only the first screen of each density level was viewed, yet even somewhat stronger preferences for higher density screens occurred. Thus, the "additional effort" hypothesis suggested from Study I was not supported.

A more likely interpretation suggests consideration by subjects of the informational qualities of the display. Figure 4 shows two screens of approximately 31% density, containing realistic content and the other nonrealistic content; and two comparable screens of approximately 53% screen density. Seemingly, in visually comparing the two nonrealistic or "content free" displays, the lower density screen will appear more spacious and easier to read. When the two screens containing realistic content, however, are compared, one must not only consider aesthetic properties, but also the amount of contextual support needed to learn. A high density design increases contextual support by presenting maximum information (both main ideas and supporting explanations or examples) on a single frame. By glancing forward or backward the student can obtain cues that facilitate the processing of a word or phrase. Low density frames minimize this contextual support which should normally disrupt the processing of information. (Consider, for example, the extreme case of reading a novel in which only one or two sentences appear on each page). It thus appears that the contextual properties of the current displays of realistic material had a greater influence on learner preferences than the aesthetic properties. Changing the context of the material or the processing demands of the task, however, might alter the relative importance of these two features. Further research is needed to substantiate this hypothesis.

Insert Figure 4 About Here

The present research calls attention to two salient problems for instructional designers and researchers in the area of CBI screen displays. First, instructional designers who base design decisions on human factors research should use caution when attempting to apply heuristics proposed for informational displays to the design of instructional displays. Informational displays, which are designed for "quick glance" reading, present information in a consistent location and vary only part of the display (e.g., monitor readouts). Instructional displays, however, are designed for slower or more deliberate processing of all the content. Thus, each has a different purpose and will typically require different design heuristics.

Second, for the reasons proposed in the preceding paragraph, subjects may apply different perspectives when reacting to nonrealistic as opposed to realistic stimulus materials in screen design studies. Although nonrealistic materials have internal validity advantages for basic research, results need to be verified with ecologically

valid materials before heuristics for screen designs are generated (Ross & Morrison, 1989).

It should also be noted that screens formatted in symbolic notation such as Twyman's (1981) may not be directly comparable to text screens of the same computed text density level due their use of solid lines of x's or o's as contrasted to lines of nonsense words or real words separated by spaces. It is recommended that researchers interested in content free stimulus materials consider the potential of approximations to English (Morrison, 1986; Shannon & Weaver, 1964) that maintain the same structure as a realistic screen without conveying meaning.

As a final point, the absence of an operational definition of low and high density screens makes it difficult to compare results across studies and to translate findings into effective design practices. To provide for consistency in design and research, the adoption of a standard method of calculating screen density is needed. Tullis' (1983) method seems appropriate for this purpose by basing screen density on the number of characters and contiguous spaces on the screen. Consistent terminology should also be used in classifying and referring to screens of varying density. For example, screens with density levels 22% or less might be labeled as low-density, those with densities between 26% and 50% as medium density, and those above 50% as high density. Although these cutoffs are arbitrary, they approximate discriminations made by subjects in the present research and would help to eliminate the current situation of one researcher's "low-density" display being structurally identical to another's "high-density" display.

It is suggested that future research on CBI screen design take three directions. First, researchers should focus on identifying optimum screen densities as opposed to minimum or maximum tolerable densities. This approach differs from earlier research in the field of instructional technology which focused on such factors as the minimum size for projected letters (cf. Phillips, 1976). Based on the present findings regarding learner preferences, the optimum density level appears to be between 31% and 53% (medium to high). Second, additional research is needed to test the generality of these findings using different types of stimulus materials (realistic in various subject areas and levels versus nonrealistic). Quantitative oriented subject material, for example, may require different design considerations than would lessons in English or history. Although the present results were similar in Studies I and II, the use of multiple frames for high external validity seems advisable to permit generalization of findings to actual lessons. Third, current research on CBI screen design has focused almost exclusively on learner preferences

for different designs. Future research needs to investigate the implications of these designs for achievement as well.

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Table 1

Proportion of Times Density Levels Within Each Paired Comparison Were Selected in Study 1

Paired Comparison												
22%	26%	22%	31%	22%	50%	26%	31%	26%	50%	31%	50%
.46	.54	.26	.74	.46	.54	.35	.65	.56	.44	.52	.48

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